Reconstructing marine fisheries catch data[1]

Dirk Zeller, and Daniel Pauly

Nowadays, as fisheries need to be managed in the context of the ecosystems in which they are embedded (Pikitch *et al.* 2004), less than full accounting for all withdrawals from marine ecosystems is insufficient. Therefore, the *Sea Around Us* strives to provide time-series of all marine fisheries catches since 1950, the first year that the Food and Agriculture Organization of the United Nations (FAO) produced its annual compendium of global fisheries statistics.

What is covered here are catches in the waters within the Exclusive Economic Zones (EEZ, Figure 1) that countries have claimed since they could do this under the United Nations Convention on the Law of the Sea (UNCLOS), or which they could claim under UNCLOS rules, but have not (such as many countries around the Mediterranean). The delineations provided by the Flanders' Marine Institute (VLIZ, see www.vliz.be) were used for our definitions of EEZs. Countries that have not formally claimed an EEZ were assigned EEZ-equivalent areas based on the basic principles of EEZs as outlined in UNCLOS (i.e., 200 nm and/or mid-line rules).

Note that we:

a) Treat disputed zones (i.e., EEZ areas claimed by more than one country) as being 'owned' by each claimant with respect to their fisheries catches, including the extravagant claims by one single country on the large swaths of the South China Sea; and
b) Treat EEZ areas prior to each country's year of EEZ declaration as 'EEZ-equivalent waters' (with open access to all fishing countries during that time).

Disclaimer*: Maritime limits and boundaries depicted on Sea Around Us maps are not to be considered as an authority on the delimitation of international maritime boundaries. These maps are drawn on the basis of the best information available to us. Where no maritime boundary has been agreed, theoretical equidistance lines have been constructed. Where a boundary is in dispute, we attempt to show the claims of the respective parties where these are known to us and show areas of overlapping claims. In areas where a maritime boundary has yet to be agreed, it should be emphasized that our maps are not to be taken as the endorsement of one claim over another.*

The United Nations Convention on the Law of the Sea (UNCLOS), initiated in the 1960s, established a framework that permitted countries to define their claims over the ocean areas, and provided agreed upon definitions for territorial seas (now defined as 12 nm), contiguous zones (24 nm, for prevention of infringements of customs, fiscal, immigration and sanitary regulations) as well as 200 nm Exclusive Economic Zones (EEZ), which now cover most shelf areas down to the continental shelf margins at which the slope of the continental shelf merges with the deep ocean seafloor. Most countries declared EEZs right after the adoption of UNCLOS as international law in 1982. Within its EEZ, the country has the sovereign right to explore and exploit, conserve and manage living and non-living resources in the water column and on the seafloor, as defined by Part V of the Law of the Sea.

[1] Adapted from: Zeller, D. and D. Pauly. 2016. Marine fisheries catch reconstruction: definitions, sources, methodology and challenges, *In*: Pauly D and Zeller D (eds.) Global Atlas of Marine Fisheries: Ecosystem Impacts and Analysis. Island Press, Washington, D.C.

The Law of the Sea also makes allowances, through the Commission on the Limits of the Continental Shelf, for countries to claim extended jurisdiction over shelf areas beyond 200 nm, if they can demonstrate that their continental shelf extends beyond the established 200 nm EEZ. National claims for EEZs and extended jurisdiction may overlap, creating areas of disputed ownership and jurisdiction. Settlements through boundary agreements may take many years to develop and are complex, resulting in numerous disputed areas and claimed boundaries.

The present text, therefore deals with catches made in about 40% of the world ocean space (i.e., EEZs), while the catches (mainly of tuna and other large pelagic fishes) made in the high seas, which cover the remaining 60%, are dealt with in Section #2.

Catches that are not associated with tuna and other large pelagic fishes, but taken by fishing countries outside their domestic waters are derived as described for 'Layer 2' in Section #4.

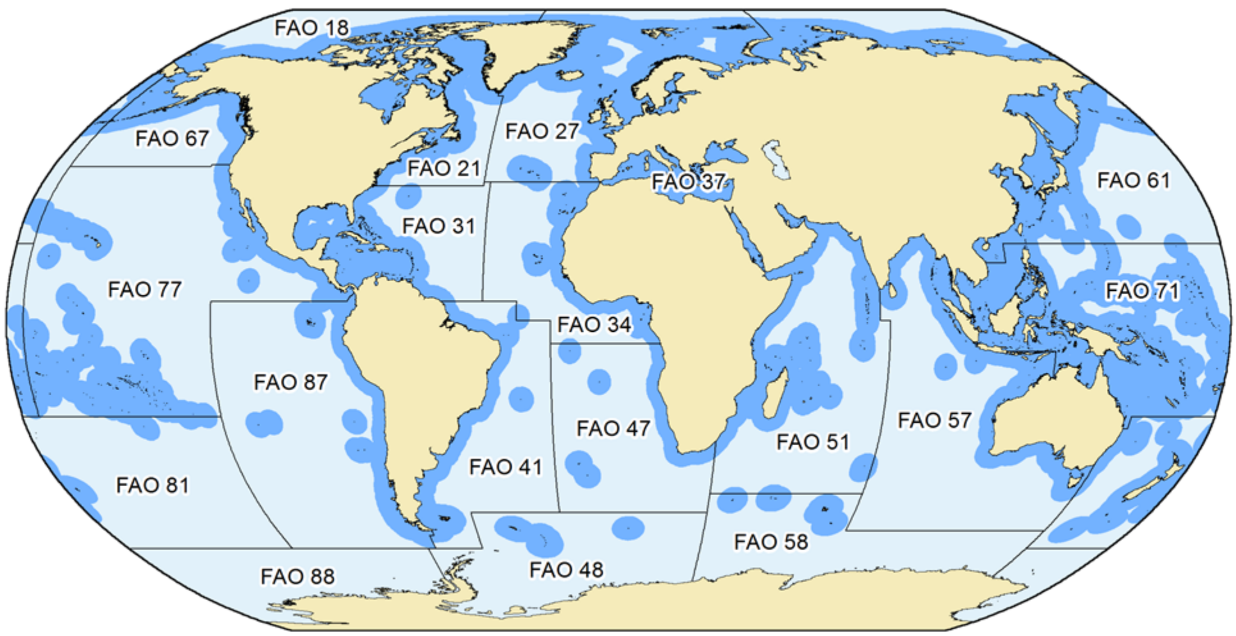

Figure 1. The extent and delimitation of countries' Exclusive Economic Zones (EEZs), as declared by individual countries, or as defined by the *Sea Around Us* based on the fundamental principles outlined in UNCLOS (i.e., 200 nautical miles or mid-line rules), and the FAO statistical areas by which global catch statistics are reported. Note that for several FAO areas, some data exist by sub-areas as provided through regional organizations (e.g., ICES for FAO area 27). The *Sea Around Us* makes use of these spatially refined data to improve the spatial allocation of catch data.

The country-by-country fisheries catch data reconstructions are based on the rational in Pauly (1998), as first implemented by Zeller *et al.* (2007). The former contribution asserted (*i*) there is no fishery with 'no data' because fisheries, as social activities throw a shadow unto the other sectors of the economy in which they are embedded, and (*ii*) it is always worse to put a value of 'zero' for the catch of a poorly documented fishery than to estimate its catch, even roughly, because subsequent users of one's statistics will interpret the zeroes as 'no catches', rather than 'catches unknown'.

Zeller *et al.* (2007) developed a six-step approach for implementing these concepts, as follows:

1. Identification, sourcing and comparison of baseline reported catch times series, i.e., a) FAO (or other international reporting entities) reported landings data by FAO statistical areas, taxon and year; and b) national data series by area, taxon and year;
2. Identification of sectors (e.g., subsistence, recreational), time periods, species, gears etc., not covered by (1), i.e., missing data components. This is conducted via extensive literature searches and consultations with local experts;
3. Sourcing of available alternative information sources on missing data identified in (2), via extensive searches of the literature (peer-reviewed and grey, both online and in hard copies) and consultations with local experts. Information sources include social science studies (anthropology, economics, etc.), reports, colonial archives, data sets and expert knowledge;
4. Development of data 'anchor points' in time for each missing data component, and expansion of anchor point data to country-wide catch estimates;
5. Interpolation for time periods between data anchor points, either linearly or assumption-based for commercial fisheries, and generally via per capita (or per-fisher) catch rates for non-commercial sectors; and
6. Estimation of total catch times series, combining reported catches (1) and interpolated, country-wide expanded missing data series (5).

Since these 6 points were originally proposed, a 7th point has come to the fore which cannot be ignored:

7. Quantifying the uncertainty associated with each reconstruction.

Here, we first expand on each of these seven reconstruction steps (Figure 2), based on the experience accumulated during the decade-long reconstruction process, when completing or guiding the reconstructions:

Step 1: Identification, sourcing and comparison of existing, reported catch times series.

Implicit in this first step is that the spatial entity be identified and named that is to be reported on (e.g., EEZ of Germany in the Baltic Sea).

For most countries, the baseline data are the statistics reported by member countries to FAO. Whenever available, we also use data reported nationally for a first-order comparison with FAO data, which often assist in identifying catches likely taken in areas beyond national jurisdiction, i.e., either in EEZs of other countries or in high seas waters. The reason for this is that many national datasets do not necessarily include catches by national distant-water fleets fishing and/or landing catches elsewhere. As FAO assembles and harmonizes data from various sources, this first-order comparison enabled catches 'taken elsewhere' to be identified and separated from truly domestic (national EEZ) fisheries (see Section #4 for the spatial layering of reconstructed datasets).

For some countries, e.g., those resulting from the breakup of the USSR, and Yugoslavia, this involved sourcing data that the now-newly emerged countries would have reported, had these countries already existed independently in 1950. In other words, we treat all countries recognized in 2010 by the international community (or acting like independent entities with regards to fisheries, e.g., the divided island of Cyprus; Ulman *et al.* 2014) as having existed from 1950-2010. This was necessary, given our emphasis on 'places', i.e., on time-series of catches taken from specific ecosystems. This also applies to islands and other territories, many of which were colonies, and which have changed status and borders since 1950.

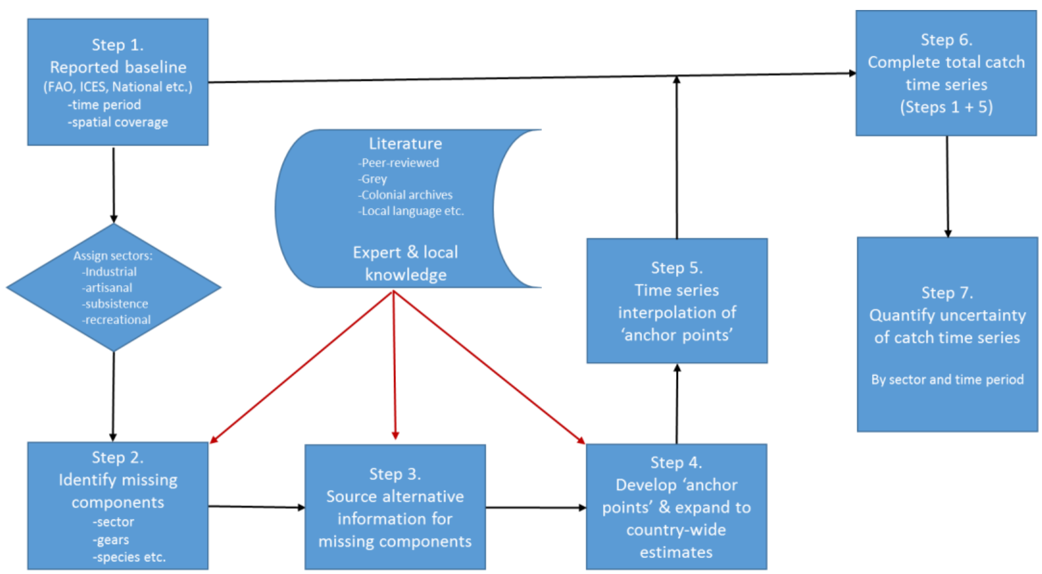

Figure 2. Conceptual representation of the 7-step catch reconstruction approach, as initially described in Zeller *et al.* (2007) and modified here.

For several countries, the baseline was provided by other international bodies. In the case of countries in Europe, the baseline data generally originated from the International Council for the Exploration of the Sea (ICES), which maintains fisheries statistics by smaller statistical areas, as required given the Common Fisheries Policy of the EU, which largely ignores EEZs. A similar area is the Antarctic continent and surrounding islands, whose fisheries are managed by the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR), where catches (including discards, a unique feature of CCAMLR) are available by relatively small statistical areas (see e.g., Ainley and Pauly 2013).

When FAO data are used, care is taken to maintain their assignment to different FAO statistical areas for each country (Figure 1). The point here is that, because they are very broad, the FAO statistical areas often distinguish between strongly different ecosystems, for example the Caribbean Sea from the coast of the Eastern Central Pacific in the case of Panama, Costa Rica, Nicaragua, Honduras and Guatemala.

Step 2: Identification of missing sectors, taxa and gear.

This step is one where the contribution of local co-authors and experts is crucial. Four fisheries sectors potentially occur in the marine fisheries of a given coastal country, with the distinction between large-scale and small-scale being the most important point (Pauly and Charles 2015):

Industrial sector: consisting of relatively large motorized vessels, requiring large sums for their construction, maintenance and operation, either domestically, in the waters of other countries and/or the high seas, and landing a catch that is overwhelmingly sold commercially (as opposed to being consumed and/or given away by the crew). All gears that are dragged or towed across the seafloor or intensively through the water column using engine power (e.g., bottom- and mid-water trawls), no matter the size of the vessel deploying the gear are here considered *industrial*, following Martín (2012), as are large pirogues (e.g., from Senegal; Belhabib *et al.* 2014) and 'baby trawlers' (in the Philippines; Palomares and Pauly 2014) capable of long-distance fishing, i.e., in the EEZ of neighboring countries. Thus, the industrial sector can also be considered *large-scale and commercial* in nature;

Artisanal sector: consisting of small-scale (hand lines, gillnets etc.) and fixed gears (weirs, traps, etc.) whose catch is predominantly sold commercially (notwithstanding a small fraction of this catch being consumed or given away by the crew). Thus, our definition of artisanal fisheries relies also on adjacency: they are assumed to operate only in domestic waters (i.e., in their country's EEZ). Within their EEZ, they are further limited to a coastal area to a maximum of 50 km from the coast or to 200 m depth, whichever comes first. This is the area what we call the *Inshore Fishing Area* (*IFA*; see Chuenpagdee *et al.* 2006). Note that the definition of an *IFA* assumes the existence of a small-scale fishery, and thus unpopulated islands, although they may have fisheries in their EEZ (which by our definition are *industrial*), have no IFA. The artisanal sector is thus defined as *small-scale and commercial*. The other small-scale sectors we recognize are subsistence and recreational fisheries, which overlap in many countries.

Subsistence sector: consisting of fisheries that often are conducted by women and/or non-commercial fishers for consumption by one's family. However, we also count as subsistence catch the fraction of the catch of mainly artisanal boats that is given away to the crews' families or the local community (as occurs, e.g., in the Red Sea fisheries; see Tesfamichael *et al.* 2012). The subsistence sector is thus defined as *small-scale and non-commercial*.

Recreational sector: consisting of fisheries conducted mainly for pleasure, although a fraction of the catch may end up being sold or consumed by the recreational fishers and their families and friends (Cisneros-Montemayor and Sumaila 2010). Unless data exist on catch-and-release mortalities in a given country, catch from recreational catch-and-release fisheries are not estimated. Often, fisheries that started out as subsistence (e.g., in the 1950s) changed progressively into recreational fisheries as economic development increased in a country and its cash economy grew. The recreational sector is thus defined as *small-scale and non-commercial*.

Finally, for all countries and territories, we account for two *catch types*: *Landings* (i.e., catch that is retained on-board and landed) and *discards*, which mainly originate from industrial fisheries. Discarded fish and invertebrates are generally assumed to be dead, except for the U.S. fisheries where the fraction of fish and invertebrates reportedly surviving is generally available on a per species basis (McCrea-Strub 2015). Due to a distinct lack of global coverage of information, we do not account for so-called under-water discards, or net-mortality of fishing gears (e.g., Rahikainen *et al.* 2004). We also do not address mortality caused by ghost-fishing of abandoned or lost fishing gear (Bullimore *et al.* 2001; He 2006; Renchen *et al.* 2010), even though it can be substantial, e.g., about 4% of trap-caught crabs worldwide (Poon 2005).

Furthermore, we exclude from consideration all catches of marine mammals, reptiles, corals, sponges and marine plants (the bulk of the plant material is not primarily used for human consumption, but rather for cosmetic or pharmaceutical use). In addition, we do not estimate catches made for the aquarium trade, which can be substantial in some areas in terms of number of individuals, but relatively small in overall tonnage, as most aquarium fish are small or juvenile specimens (Rhyne *et al.* 2012). Note that at least one regional organization (the Secretariat of the Pacific Community, SPC) is coordinating the tracking of catches and exports of Pacific island countries involved in this trade (see, e.g., Wabnitz and Nahacky 2014). Finally, we do not explicitly address catches destined for the Live Reef Fish Trade (LRFT; see Warren-Rhodes *et al.* 2003), although, given that these fisheries are often part of normal commercial operations, the catch tonnages of the LRFT is assumed to be addressed in our estimates of commercial catches. Our subsequent estimates of landed value of catches using the global ex-vessel fish price database (see Section #6) will therefore undervalue the catch of any taxa destined directly to the LRFT. All the data omissions indicated above are additional factors why our reconstructed total catches are a conservative metric of the impacts of fishing on the world's marine ecosystems.

For any country or territory we check whether catches originating from the above fishing sectors are included in the reported baseline of catch data, notably by examining their taxonomic composition, and any metadata, which were particularly detailed in the early decades of the FAO 'Yearbooks' (e.g., FAO 1978).

The absence of a taxon known to be caught in a country or territory from the baseline data (e.g., cockles gleaned by women on the shore of an estuary) can also be used to identify a fishery that has been overlooked in the official data collection scheme, as can the absence of reef fishes in the coastal data of a Pacific Island state (Zeller *et al.* 2015). Note, however, that, to avoid double counting, tuna and other large pelagic fishes, unless known to be caught by a local small-scale fishery (and thus not always reported to a Regional Fisheries Management Organization or RFMO), are not included in this reconstruction step (industrial large pelagic catches are reconstructed using a global approach, see Section #2).

Finally, if gears are identified in national data, but catch data from a gear known to exist in a given country are not included, then it can be assumed that its catch has been missed, as documented by Al-Abdulrazzak and Pauly (2013) for weirs in the Persian Gulf.

Step 3: Sourcing of available alternative information sources for missing data.

The major initial source of information for catch reconstructions is governments' (and specifically their Department of Fisheries or equivalent agency) websites and publications, both online and in hard copies. Contrary to what could be expected, it is often not the agency responsible for fisheries which supplies the catch statistics to FAO, but other agencies, e.g., some statistical office or agency, with the result that much of the granularity of the original data (i.e., catch by sector, by species or by gear) may be lost even before it reaches Rome. Furthermore, the data request form sent by FAO each year to each country does not explicitly encourage improvements or changes in taxonomic composition, as the form contains the country's previous years' data in the same composition as submitted in earlier years, and requests the most recent year's data. This encourages the pooling of detailed data at the national level into the taxonomic categories inherited through earlier (often decades old) FAO reporting schemes (see e.g., Bermuda, Luckhurst *et al.* 2003). Thus, by getting back to the original data, much of the original granularity can be regained during reconstructions (e.g., Bermuda reconstruction, Teh *et al.* 2014). A second major source of information on national catches are international research organizations such as FAO, ICES, or SPC, or a RFMO such as NAFO, or CCAMLR (Cullis-Suzuki and Pauly 2010), or current or past regional fisheries development and/or management projects (many of them launched and supported by FAO), such as the BOBLME Project. All these organizations and projects issue reports and publications describing - sometimes in considerable details - the fisheries of their member countries. Another source of information is obviously the academic literature, now widely accessible through Google Scholar.

A good source of information for the earlier decades (especially the 1950s and 1960s) for countries that formerly were part of colonial empires (especially British or French) are the colonial archives in London (British Colonial Office) and the 'Archives Nationales d'Outre-Mer', in Aix-en-Provence, and the publications of O.R.S.TO.M., for the former French colonies. A further good source of information and data are also non-fisheries sources, including household- and/or nutritional-surveys, which can be of great use for estimating unreported subsistence catches. We find the Aquatic Sciences and Fisheries Abstracts (ASFA) and the University of British Columbia library services (and especially its experienced librarians) and its Interlibrary Exchange invaluable for tracking and acquiring such older documents.

Our global network of local collaborators is also crucial in this respect, as they have access to key data sets, publications and local knowledge not available elsewhere, often in languages other than English.

The reconstructions themselves should be consulted for fine-grained information on specific countries or territories, all of which are available online on each EEZ webpage. Every reconstruction we undertake is thoroughly documented and published, either in the peer-reviewed scientific literature, or as detailed technical reports in the publicly accessible and search-engine indexed *Fisheries Centre Research Reports* series, or the *Fisheries Centre Working Paper* series, or as reports issued by regional organizations (e.g., BOBLME 2011).

Step 4: Development and expansion of 'anchor points'.

'Anchor points' are catch estimates usually pertaining to a single year and sector, and often to an area not exactly matching the limits of the EEZ or IFA in question. Thus, an anchor point pertaining to a fraction of the coastline of a given country may need to be expanded to the country as a whole, using fisher or population density, or relative IFA or shelf area as raising factor, as appropriate given the local condition. In all cases, we are aware that case studies underlying or providing the anchor point data may had a case-selection bias (e.g., representing an exceptionally good area or community for study, compared to other areas in the same country), and thus we use any raising factors very conservatively. Hence, in many instances, we may actually be underestimating any raised catches.

Step 5: Interpolation for time periods between anchor points.

Fishing, as a social activity involving multiple actors are very difficult to govern; particularly, fishing effort is difficult to reduce, at least in the short term. Thus, if anchor points are available for years separated by multi-year intervals, it will be usually more reasonable to assume that the underlying fishing activity went on in the intervening years with no data. Strangely enough, this 'continuity' assumption we take as default is something that some colleagues are reluctant to make, which is the reason why the catches of, e.g., small-scale fisheries monitored intermittingly often have jagged time-series of reported catches. Exceptions to such continuity assumptions are obvious major environmental impacts such a hurricanes or tsunamis (e.g., cyclones Ofa and Val in 1990-1991 in Samoa; Lingard *et al.* 2012) or major socio-political disturbances, such as military conflicts (e.g., 1989-2003 Liberian civil war; Belhabib *et al.* 2013), which we explicitly consider with regards to raising factors and the structure of time series. In such cases, our reconstructions mark the event through a temporary change (e.g., decline) in the catch time-series (documented in the text of each catch reconstruction), if only to give pointers for future research on the relationship between fishery catches and natural catastrophes or conflicts. As an aside, we note here that the absence of such a signal in the officially reported catch statistics (e.g., a reduction in catch for a year or two) in countries having experienced a major event of this sort (e.g., Cyclone Nargis in 2008 in Myanmar) is a sure sign that their official catch data are manufactured or at least questionable, without reference to what occurs on the ground (see also Jerven 2013). Overall, our reconstructions assume - when no information to the contrary is available - that commercial catches (i.e., industrial and artisanal) between anchor points can be linearly interpolated, while for non-commercial catches (i.e., subsistence and recreational), we generally use population or number of fishers trends over time to interpolate between anchor points (via per capita rates).

Radical and rapid effort reductions (or even their attempts) as a result of an intentional policy decision (and actual implementation) do not occur widely. One of the few exceptions that comes to mind is the trawl ban of 1980 in Western Indonesia, whose partial implementation is discussed in Pauly and Budimartono (2015). The ban had little or no impact on official Indonesian fisheries statistics for Central and Western Indonesia, another indication that they, also, may have little to do with the realities on the ground

Step 6: Estimation of total catch times series by combining (1) and (5).

A reconstruction is completed when the estimated catch time-series derived through steps 2-5 are combined and harmonized with the reported catch of Step 1. Generally, this will result in an increase of the overall catch, but several cases exist when the reconstructed total catch was lower than the reported catch. The best documented case of this situation is that of mainland China (Watson and Pauly 2001), whose over-reported catches for local waters in the North-west Pacific are inflated by under-reported catches taken by Chinese distant water fleets, which, in the 2000s, operated in the EEZs of over 90 countries, i.e., in most parts of the world's oceans (Pauly *et al.* 2014). The step of harmonizing reconstructed catches with the reported baselines obviously goes hand-in-hand with documenting the entire procedure, which is done via a text that is formally published in the scientific literature, or pending publication, is made available online as either a contribution in the *Fisheries Centre Research Reports* series or as a *Fisheries Center Working Paper*. These documents (available online via www.seaaroundus.org) should be consulted by anyone intending to work with our data.

Several reconstructions were performed earlier in the mid- to late 2000s, when official data (i.e., FAO statistics or national data) were only available to earlier years. All these cases were subsequently updated to the most recent year of data, either by detailed reconstruction updates or by forward carry procedures (e.g., Zeller *et al.* 2015) in line with each country's individual reconstruction approach to estimating missing catch data.

Step 7: Quantifying the uncertainty in (6).

On several occasions, after having submitted reconstructions to peer-reviewed journals, we were surprised by the vehemence with which referees insisted on a quantification of the uncertainty involved in our reconstructions. Our surprise was due to the fact that catch data, in fisheries research, are never associated with a measure of uncertainty, at least not in the form of anything resembling confidence intervals. We pointed out that the issue at hand was not one of *precision* (i.e., whether, upon re-estimation, we could expect to produce similar results), but about *accuracy*, i.e., attempting to eliminate a systematic bias, a type of error which statistical theory does not really address. However, this is an ultimately frustrating argument, as is the argument that officially reported catch data, despite being themselves sampled data (e.g., from commercial market sampling, Ulman *et al.* 2015; or landings site sampling, Jacquet *et al.* 2010), with unknown but potentially substantial margins of uncertainty, are never expected or thought to require measures of uncertainty.

Hence, we applied to all reconstructions the procedure in Zeller *et al.* (2015) for quantifying their uncertainly, which is inspired from the 'pedigrees' of Funtowicz and Ravetz (1990) and the approach used by the Intergovernmental Panel on Climate Change to quantify the uncertainty in its assessments (Mastrandrea *et al.* 2010).

Table 1. 'Scores' for evaluating the quality of time series of reconstructed catches, with their approximate confidence intervals (IPCC criteria from Figure 1 of Mastrandrea *et al.* 2010); the percent intervals, here updated from Zeller *et al.* (2015), are adapted from Ainsworth and Pitcher (2005) and Tesfamichael and Pitcher (2007).

Score		**+/- (%)**	**Corresponding IPCC criteria***
4	Very high	10	High agreement & robust evidence
3	High	20	High agreement & medium evidence **or** medium agreement & robust evidence
2	Low	30	High agreement & limited evidence **or** medium agreement & medium evidence **or** low agreement & robust evidence.
1	Very low	50	Low agreement & low evidence

Mastrandrea *et al.* (2010) note that "confidence increase" (and hence confidence intervals are reduced) "when there are multiple, consistent independent lines of high-quality evidence".

This procedure consist of the authors of the reconstructions attributing to each reconstruction a score for each catch estimate by fisheries sector (industrial, artisanal, etc.) in each of three periods (1950-1969, 1970-1989 and 1990-2010) expressing their evaluation of the quality of the time series, i.e., (1) 'very low', (2) 'low', (3) 'high' and (4) 'very high'. Note the absence of a 'medium' score, to avoid the non-choice that this easy option would represent. Each of these scores corresponds to a percent range of uncertainty (Table 1) adapted from Monte-Carlo simulations in Ainsworth and Pitcher (2005) and Tesfamichael and Pitcher (2007). The overall score for the reconstructed total catch of a sector and/or period can then be computed from the mean of the scores for each sectors, weighted by their catch, and similarly for the relative uncertainty. Alternatively, the percent uncertainty for each sector and period can be used for a full Monte Carlo analysis.

Foreign and illegal catches

Foreign catches are catches taken by *industrial* vessels (by definition, all foreign fishing in the waters of another country is deemed to be industrial in nature) of a coastal state in the EEZ, or EEZ-equivalent waters of another coastal state. As the High Seas legally belong to no one (or to everybody, which is here equivalent), there can be no 'foreign' catches in the High Sea. Prior to UNCLOS, and the declaration of EEZs by maritime countries, foreign catches were illegal only if conducted within the *territorial* waters of such countries (generally, but not always 12 nm). Since the declarations of EEZs by the overwhelming majority of maritime countries, foreign catches are considered illegal if conducted within the (usually 200 nm) EEZ and without access agreement with the coastal state (except in the EU, whose waters are managed by a 'Common Fisheries Policy' which implies a multilateral 'access agreement').

Such agreements can be tacit and based on historic rights, or more commonly explicit and involving compensatory payment for the coastal state. The *Sea Around Us* has created a database of such access and agreements, which is used to allocate the catches of distant-water fleets to the waters where they were taken (see Section #4).

Many catch reconstructions, in addition to identifying the catch of domestic fleets, often at least mention the foreign countries fishing in the waters of the country they cover (information we use in our access database), while other reconstructions explicitly quantify these catches (particularly in West Africa, see Belhabib *et al.* 2012).

This information is then combined and harmonized with:

a) the catches deemed to have been taken outside a country's EEZ, as derived in Step 1 above and further detailed in Section #4, and
b) the landings of countries reported by FAO as fishing outside the FAO areas in which they are located (e.g., Spain in FAO Area 27 reporting catches from Area 34, Figure 1), which always identifies these catches as distant-water landings, and thus allows estimation of the catch by foreign fisheries in a given area and even EEZ.

Conservative estimates of discards are then added to these foreign landings, estimated from the discarding rates of the domestic fisheries operating in the countries and/or FAO areas in question.

Catch composition

The taxonomy of catches is what allows catches to be mapped in an ecosystem setting, as different taxa have different distribution ranges and habitat preferences (see Section #3). Also, temporal changes in the relative contribution of different taxa in the catch data also indicate changes in fishing operations and/or in dominance patterns in exploited ecosystems. Thus, various ecosystem state indicators can be derived from catch composition data, e.g., the 'mean temperature of the catch' which tracks global warming (Cheung *et al.* 2013), 'stock-status plots' which can provide a first-order assessment of the status of stocks (Kleisner *et al.* 2013) and the marine trophic index, which reveal instances of "fishing down marine food webs" (Pauly *et al.* 1998; Pauly and Watson 2005; Kleisner *et al.* 2014, see also www.fishingdown.org).

Most statistical systems in the word manage to present at least some of their catch in taxonomically disaggregated form (i.e., by species), but many report a large fraction of their catch as over-aggregated, uninformative categories such as 'other fish' or 'miscellaneous marine fishes' (or 'marine fishes nei' [not elsewhere included]). Interestingly, many official national datasets have better taxonomic resolution than the data reported to FAO by national authorities. It is highly likely that this is largely the result of the design of the data request form that FAO distributes to countries each year, which does not actively encourage (nor even suggest) that more detailed national taxonomic resolution data should be provided whenever possible. We have attempted to reduce the contribution of such over-aggregated groups by using taxonomic information from a variety of local and regional studies The species and higher taxa in the catch of a given country or territory can thus belong to either one three groups:

(1) Species or higher taxa that were already included in the baseline reported data;
(2) Species or higher taxa into which over-aggregated catches have been subdivided using two or more sets of catch composition data, such that the changing catch composition data reflect at least some of the observed changes of fishing operations and/or in the underlying ecosystem;
(3) Species or higher taxa into which over-aggregated catches have been subdivided using only one set of catch composition data, and which therefore cannot be expected to reflect changes in catch compositions due to changes in fishing operations and/or changes in the underlying ecosystem. This score is also applied in cases where no local/national information on the taxonomic composition was available, and thus a taxonomic resolution from neighbouring countries was applied.

We have labelled every taxon in the catch time-series of every country with (1), (2) or (3) such that (3) and perhaps also (2) are NOT used to compute indicators such as outlined above (they would falsely suggest an absence of change) – although we fear that this will still occur.

In summary, the approach we developed and utilized for undertaking the catch reconstructions for every maritime country/territory in the world consists of a well-structured system for utilizing all available data sources, and applying a conservative, but comprehensive integration approach.

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Section 2

Reconstructing catches of large pelagic fishes[2]

Frédéric Le Manach, Andrés M. Cisneros-Montemayor, Dirk Zeller and Daniel Pauly

Despite tuna fisheries being among the most valuable in the world (FAO 2012), as well as the considerable interest by civil society in the management of large pelagics, there are, to date, no global and comprehensive spatial datasets presenting the historical industrial catches of these species.

Here, we present the methods used to produce a first comprehensive spatial set of large pelagics fisheries catch data.[3] To achieve this, we assembled various existing tuna datasets (Table 1), and harmonized them using a rule-based approach.

[2] Adapted from: Le Manach, F, Chavance, P, Cisneros-Montemayor, AM, Lindop, A, Padilla, A, Zeller, D, Schiller, L and Pauly, D. 2015. Global catches of large pelagic fishes, with emphasis on the High Seas, *In:* Pauly D and Zeller D (eds.) *Global Atlas of Marine Fisheries: Ecosystem Impacts and Analysis*. Island Press, Washington, D.C.